Base Catalyzed Decomposition Process Proven On Guam

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INTRODUCTION

The Base Catalyzed Decomposition Process (BCDP) technology was initially developed by the U.S. EPA for remediating PCB-contaminated soil. It is also applicable to soil contaminated with other chlorinated as well as nonchlorinated organics. The basic equipment and operating procedures are similar to those of a thermal desorber, but several new technologies are utilized:

- The addition of sodium bicarbonate promotes lower temperature desorption and partial destruction of chlorinated organics.
- Steam sweep creates an inert atmosphere above the hot soil. The inert gas suppresses the formation of oxidative combustion products like dioxin and eliminates the possibility of combustion occurring in the Rotary Reactor. Any combustion would produce a positive pressure and contaminants could potentially be released into the environment.
- A novel control system allows a Wet Electrostatic Precipitator (WESP) in the off-gas treatment system to operate without the danger of a fire or explosion, regardless of the levels of organics in the off-gas.
- Most of the contaminants (such as PCBs) are condensed and directly removed in a concentrated form. This minimizes the volume of residuals produced.

These innovations combine to produce a cost-effective soil remediation technology that is environmentally safe to operate with an off-gas cleaning system that is over 99.999% efficient.

Technology Applicability

BCDP can be used to treat the same type of material that can be treated by a thermal desorber; that is, contaminated soils, sludges, and filter cakes. If PCBs (and possibly other chlorinated compounds) are treated, the bicarbonate catalyst will increase plant efficiency by allowing the soil to be cleaned at a lower temperature and chemically destroying some of the PCBs.

Although the BCDP was initially designed to treat PCB-contaminated soil, its performance on other types of contaminants can be predicted. The BCDP will remove both volatile and semivolatile compounds from soil, including very low volatility chlorinated organics. The performance of the Air Pollution Control System (APCS) depends largely on the nature of the organics being removed. High boiling point organics, such as PCBs, are largely removed by condensation and captured on either the Wet Electrostatic Precipitator (WESP) or the High Efficiency Mist Eliminator (HEME). Semivolatile water soluble organics are captured in the WESP water by solubilizing into that water. Volatile non-water soluble organics and residual PCB vapors are captured by the carbon at the end of the air capture system.

Compounds such as PCBs, which may react with oxygen at elevated temperatures to form even more hazardous compounds such as dioxins, are especially suited to the BCDP. The inert steam atmosphere in the Rotary Reactor and throughout the air capture system excludes most of the oxygen. The sodium bicarbonate breaks down, releasing carbon dioxide and water to add additional inert gases to the system. At high temperatures, in the absence of oxygen, some pyrolysis will occur and actually break down larger molecules into smaller and, in many cases, less toxic compounds.

The primary factors affecting contaminant removal in the Rotary Reactor are temperature and residence time. As an example, PCB-contaminated soil requires a temperature of approximately 600°F at a residence time of about one-half hour. As the temperature is raised, the residence time can be reduced. These numbers are approximate because the type of soil that the PCBs are in is also a factor. The total quantity of organics that is released in the Rotary Reactor is an important factor in the overall economics of the system. Since only partial destruction of PCBs is caused by the bicarbonate, all the organics that are released will likely be contaminated with PCBs. This contaminated residual must be disposed of off-site, typically by incineration. The total amount of organics that will be released are estimated by running a simple ash test at the maximum Rotary Reactor operating temperature. The weight loss of the sample (on a moisture-free basis) will approximate the percentage of organics that will be driven off in the Rotary Reactor. Naturally occurring organics such as decaying vegetation, roots, insects, etc., will be pyrolized in the Rotary Reactor and removed as a wide variety of organic compounds. If a soil, for example, is 1,000 ppm PCB and 5% other organics that will volatilize, the maximum volume reduction will be about 95%. Because some of these organics are mixed with fines from the rotary reactor and deposited on air and water phase carbon, the actual volume reduction will be less.

Table 1 lists the codes for some specific Resource Conservation and Recovery Act (RCRA) waste that can be treated by this technology. These compounds can all be successfully treated in standard thermal desorbers, therefore they should be treatable in the BCDP. General contaminant groups that can be treated by the BCDP are shown in Table 2. This table is based on current available information for treatment by thermal desorption.

Table 1. RCRA Codes for Wastes Treatable by the BCDP

Wood Treating Wastes	K001
Dissolved Air Flotation Float	K048
Slop Oil Emulsion Solids	K049
Heat Exchanger Bundles Cleaning Sludge	K050
API Separator Sludge	K051
Tank Bottoms (Leaded)	K052

Table 2. General Contaminant Groups Treatable by BCDP

Nonhalogenated and Halogenated Volatiles and Semivolatiles
PCBs
Pesticides
Dioxins/Furans
Organic Cyanides
Volatile Metals

Individual site conditions must be considered to determine the effectiveness of the BCDP. For example, PCBs are released fairly quickly from the coral matrix found in Guam. It is expected that PCBs would be more tightly bound to clay, and that higher temperatures or longer residence times would be required if the PCBs were on clay instead of coral. If the PCBs at a particular site were found together with high levels of nonhazardous organics, the quantity of residuals that would be generated for off-site disposal would be increased.

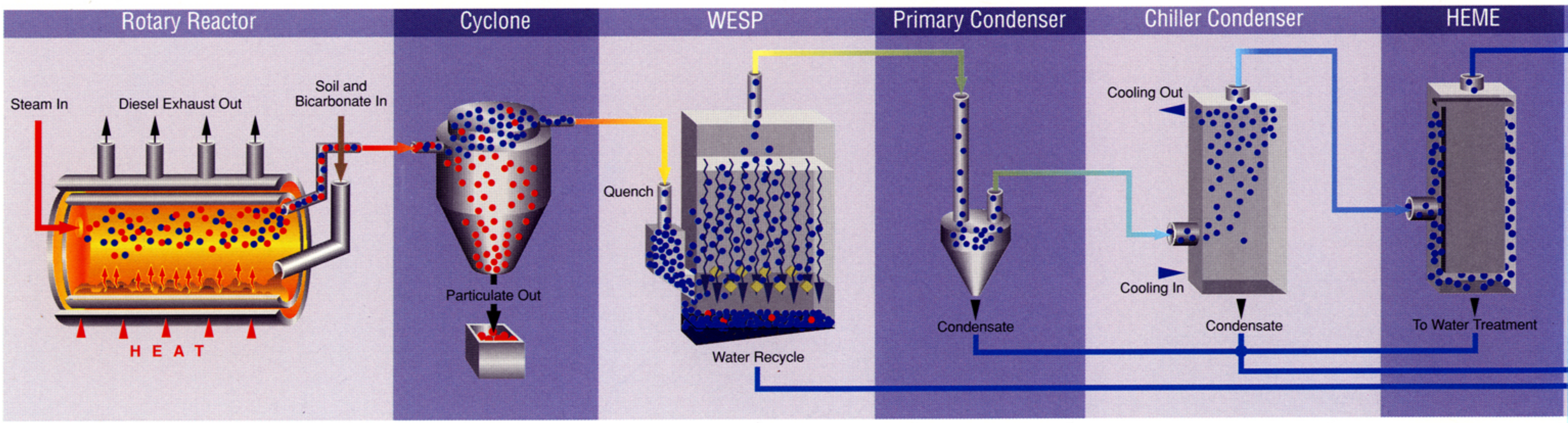
How BCDP Works

The diagram below shows a general schematic of the BCDP process. Soil is crushed, mixed with bicarbonate, and introduced into the Rotary Reactor. The Rotary Reactor in Guam is a standard calciner with a carbon steel shell. As the soil passes through the inside of the rotating shell, diesel burners heat the shell to a temperature of about 900°F. As the soil passes through the unit, the PCBs and other organics volatilize into a vapor and enter the atmosphere in the interior of the shell. Steam is introduced countercurrent to the soil addition. As the organics leave the solid phase and enter the gas phase in the Rotary Reactor, the steam sweeps them out of the Rotary Reactor to the cyclone. The cyclone is insulated and the bottom of the cyclone is electrically heated to minimize the amount of condensation and maintain a high temperature. Larger dust particles are removed in the cyclone by centrifugal force and fall out into a collection drum.

The gas passes out of the cyclone to the WESP. The gas continuously cools as it exits the Rotary Reactor until it enters the WESP. As the gas cools, the heavy semivolatile organics will condense and form an aerosol (micron and submicron size droplets of organic liquid). When the gas enters the WESP, it is given an electrostatic charge and then passes through a vertical tube sheet. The tubes in the tube sheet have an opposite charge to that on the particles in the gas. This causes the particulate and aerosols in the gas to be attracted to the tube walls. As these solid particulates and liquid aerosols contact the walls of the tube, they agglomerate and are washed off by water which is constantly sprayed into the tubes. The WESP is almost 100% efficient at removing particulate and aerosols above three microns in size and over 99% efficient in removing particulate and aerosols less than three microns in size.

Although the WESP is ideally suited for removing these small particles, this is the first application of a WESP in this configuration. Because of the strong electrostatic charges within the WESP—up to 40,000 volts — the WESP periodically sparks. This spark provides an ignition source, and if the gas in the WESP is within the flammability or explosive limits, a fire or explosion could result. In the BCDP, steam is used to exclude oxygen from the WESP. By maintaining an oxygen level below 10%, the WESP can be safely operated with any level of organics in the entering gas stream.

The gas exiting the WESP is very clean. It is essentially free of particulate, and organics that will condense at 212°F have for the most part been removed. This gas stream then enters the primary condenser where the steam is condensed. The primary condenser is a vertical shell and tube heat exchanger using cooling tower water on the shell side. The temperature of the gas is reduced from 212°F to 80-90°F, condensing and removing almost all the steam. After the primary condenser the only gases left are air that has infiltrated the system and any noncondensable gases that were generated in the Rotary Reactor. In the BCDP on Guam, the steam sweep gas flow is about 100 actual cubic feet per minute (ACFM). The gas flow leaving the primary condenser is less than 10 ACFM, over a 90% reduction in gas volume. This reduced gas volume allows



a corresponding size reduction in the remaining components of the system. This feature is unique to the BCDP system on Guam.

The off-gas leaving the primary condenser passes to the chiller condenser. The chiller condenser is a heat exchanger using an ethylene glycol water solution on the tube side. In this unit the gas is cooled to about 40°F. This condenses additional organics and additional water.

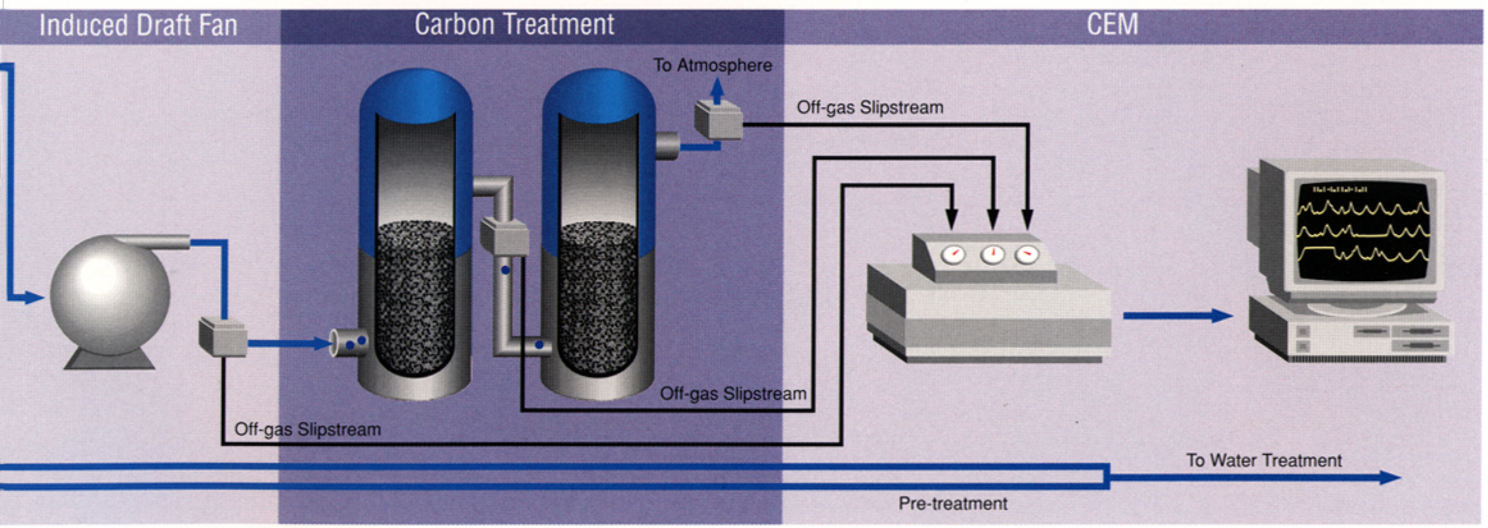
The gas leaves the chiller condenser and travels to the HEME. The HEME is a tightly woven fiberglass pad about three inches thick. As the gas passes through this pad, organic aerosols that condensed because of the additional cooling after the WESP are removed. The removal efficiency of the HEME is similar to the WESP, virtually 100% efficient on particles above three microns and over 99% efficient on particles less than three microns in size.

Although the HEME and WESP both remove the same type of material, they do so by very different mechanisms and are positioned in the APCS to complement each other. Solid particulate and aerosols are collected on tube walls in the WESP and flushed off with water. While the HEME will remove solid particulate, they will not drain out of the fabric. If particulate steadily accumulates on the surface of the HEME, it will eventually plug the fabric. Low viscosity organics that collect in the HEME will naturally drain out of the unit. High viscosity organics, however, will not drain and will accumulate and plug the HEME. These high viscosity organics and particulate that the HEME will not handle are removed in the WESP.

The HEME serves two major functions. It collects the organic aerosols that form after the cooling that occurs in the gas stream between the WESP and the HEME, and it acts as a backup should the WESP experience a power outage. The HEME is very close to being a fail-safe device. If the WESP should stop functioning, the HEME will receive the high viscosity organics and particulate and will remove them with the same efficiency seen in the WESP. They will, however, slowly plug the HEME until the pressure drop becomes excessive and the HEME has to be taken off line. For this reason, two HEME units are located in parallel. If one unit should plug, the gas stream is switched to the second unit and the first unit is changed out. While the WESP is operating, the HEME will receive a solids-free gas stream containing low viscosity organic aerosols. Under these conditions, the HEME has a very long life.

After the HEME, the gas passes through the ID fan. This fan is drawing gases from the Rotary Reactor throughout the entire air capture system. Because most of the gas is removed in the primary condenser, the ID fan capacity is very small. The WESP is a very low pressure drop device and the HEME, operated with low air flow, is also a low pressure drop device. In Guam, the ID fan pulls a vacuum of only two to three inches of water.

After the ID fan, the gas passes through the final polishing carbon and out the vent stack. This carbon will remove most of the residual organic vapors, including some residual PCB vapors that still exist even at the ambient temperature at which the carbon operates. Because of the chiller condenser, the carbon receives a dry gas stream. The gas leaving the primary condenser is water saturated. When this gas is cooled to 40°F in the chiller condenser, it is still water saturated. However, after it leaves the chiller condenser it heats up. The lowest ambient temperature on Guam is about 65°F. Without the chiller condenser, this gas stream would still be cooling as it passed through the carbon and would deposit water on the carbon. By running the carbon dry, its capture capacity is significantly increased.



Performance Data

As this document is being written, the BCDP on Guam has processed about 2,000 tons of PCB-contaminated soil. The system has operated at rates of 1.7 tons per hour. The BCDP will easily achieve total PCB concentration below 2 ppm in the treated soil. Because the project cleanup limit is 2 ppm per congener, the total PCB concentration in the reactor product can be as high as 14 ppm.

The APCS has operated well. The initial operation of the system in the summer of 1995 was performed without the WESP and Chiller Condenser because of special fabrication requirements. A stack test performed by the Navy shortly after start-up showed that emissions were very low. PCB removal was about five 9s, and levels of other organics in the stack were very low. Average combined dioxin and furan concentrations were 32 nanograms per cubic meter. The Navy plans to perform another stack test in the summer of 1996. With all the APCS equipment now in place, even lower stack emissions are anticipated.

The steam sweep and WESP have been easy to operate. To insure that oxygen is below 10%, the WESP alarms at 203°F and the power to the WESP automatically shuts down at 188°F. The hot kiln off-gas supplies sufficient heat to maintain the WESP temperature in the safe zone, typically between 206°F and 210°F. After the primary condenser, where the steam is condensed, the gas flow is reduced to 10 cubic feet per minute (CFM), as compared to 180 CFM before the steam sweep was added to the system.

The WESP is removing over 99% of the particulate in the off-gas, and appears to remove most of the organics. Water is recirculated from the WESP sump to the spray nozzles above the sump that flush the WESP tubes. A blowdown of about one gallon per minute (gpm) is sufficient for the removal of contaminants from the WESP. This one gpm stream contains most of the contaminants from the off-gas stream and is isolated and pretreated before being sent to the water treatment plant.

Before the WESP was operated, a venturi scrubber was used to remove fines from the gas stream before the gas passed through the High Efficiency Mist Eliminator (HEME). The scrubber was not efficient at removing organic mists, and the HEME element would last about a month before the pressure drop became excessive (over 25 inches water column (w.c.) and the HEME had to be replaced. After about a month of operation with the WESP instead of the scrubber, the HEME pressure drop is less than 0.5 inches w.c.

Based on 15,000 tons of material, operating costs and prorated capital costs on Guam are $450 per ton. The production rate is 1.7 tons per hour, with 85% system availability. These costs are inflated due to the high per diem, lodging, and travel costs (all plant personnel are from the mainland). If the per diem and lodging costs are removed, the cost drops to $322 per ton.